the lumbar diapophyses. A few years ago I defined a genus, based on several species from the Miocene of Maryland, in which the lumbar diapophyses are spiniform. Supposing the *Priscodelphinus harlani* of Leidy to possess the same character I retained the same generic name for the Maryland species. After an examination of considerable material from the New Jersey locality, including bones of *P. harlanii*, I have failed to observe a single species with the spinous processes alluded to. It thus becomes evident that *Priscodelphinus* must be retained for the species termed by me *Tretosphys*, while that for which I retained the name *Priscodelphinus* must receive a new one. For this I propose *Belosphys* with *B. spinosus*, Cope, as type, and *B. atropius*, *B. conradi* and *B. stenus* as species. At the same time I add that the presence of *Ixacanthus coelospondylus*, Cope, in the New Jersey Miocene mentioned in Cook's Geological Survey of New Jersey by the writer, is doubtful.

Total number of species, thirty-three.

ORIGIN OF THE LOWER SILURIAN LIMONITES OF YORK AND ADAMS COUNTIES.

By Persifor Frazer, Jr.

(*Read before the American Philosophical Society, March* 19, 1875.)

The three great deposits of Lower Silurian limestone which occur in this State, are : 1st. That of the Chester Valley which begins at Willow Grove, in Montgomery county, and terminates about a mile west of Minerstown, in Lancaster county ; 2d. The great Lancaster and York county basin which, commencing about a mile northeast of Morgantown, crosses the Susquehanna River in two prongs, the longer (most northerly) of which terminates almost on Mason and Dixon's line in the southeast corner of Adams county; and 3d. The great valley, *par excellence*, which enters the State at Easton on the Delaware River, and passes into Maryland in a wide belt, which stretches fifteen miles east and the same distance west of Middleburg, Franklin county.

Accompanying all these limestone basins are belts of iron ore which crop out at tolerably uniform distances below their edges. In the still lower measures of the Silurian, and above the Potsdam sandstone, are other belts of ore entirely disconnected from the limestone ores.

In the first Report of the Geology of Pennsylvania (Vol. I, p. 218), it is stated of the Rathfon Ore Banks of Lancaster county, that in this, as in most of the other iron veins connected with the magnesian limestones,

the position of the ore is precisely at the junction of the limestone and slate. "It is indeed only a very ferruginous variety of the metamorphosed slate regularly stratified and intercalated with it."

Again, "west of the Gantner Ore Diggings," * * "the ore lies in decomposed sandy talco-micaceous slate between the sandstone and an outcrop of limestone south of it." And just beyond, "The Conewango Ore Bank lies at the junction of the Auroral limestone and the talco-micaceous slates of the primal series." In another place, the section of this limestone at Strickler's Run is given, commencing at the lowest number of the series:

1. Limestone, 150 feet.
2. Blue talcoid slate, 200 feet.
3. Limestone, 15 feet.
4. Dark-blue slate, 20 feet.
5. Limestone (?).
6. Bluish talcoid slate, 200 feet.
7. Limestone (?).

(Total 405 + feet).

Of the iron ores of York county, it is stated simply that a belt is traceable along the southern edge of the limestone towards Littlestown, but has been long neglected, owing probably to its containing a considerable portion of the oxide of manganese. All these statements agree in placing the limonites just beneath the Auroral limestone. The older ores seem not to be mentioned at all.

The ores of York county are of three kinds: 1st, pyritiferous and partly magnetic limonites; 2d, the limonites proper, which were the special objects of my investigation last summer; and 3d, the micaceous and magnetic ores of the Mesozoic sandstone. The first fact of importance with regard to the second of these kinds, is that (corroborated by Prof. Prime), they never occur far from the Auroral limestone, but always on its edges, thus skirting the entire basin (when not overlain by the Red Sandstone), and forming a line of ore wherever, within the limits of the basin, from folding and subsequent denudation, an edge of this Auroral limestone is exposed. 2d. They are *almost* always in the form of segregations in yellowish and bluish clay. 3d. Not only is each belt of ore made up of small pockets and nests lying without regularity in the decomposed slates constituting the clay, but in some cases the belt itself is capricious and appears to run out whenever the rock becomes less easily decomposable.

I should hesitate to ascribe the source of this iron supply to the minute crystals of pyrite which undoubtedly permeate some horizons of the great Calcareous deposit, both because their number and the porousness of the limestone as observed in connection with the ore,

seem to bear no relation to the latter. Besides, the supply of iron from such minute crystals in the limestone would be insufficient to produce the limonite beds. It seems much more probable that the source of the supply of iron were the pyrite crystals of the slates which, once towering high in the air, have been carried down by denudation and deposited in the Atlantic. Even these slates which are not so situated as to permit the percolation of water through them, exhibit a porous structure, the pores being filled with brown ochreous limonite, and this occurs to a considerable depth, and the slate merges by imperceptible degrees in a direction normal to the plane of bedding, first into completely metasomatized pseudomorphs of limonite after pyrite (but still retaining the form of the latter); then the same with a kernel of pyrite; then the pyrite itself, first with a shell and then with a mere stain of ferric hydrate; and finally the same slates are revealed porphyritic from the pyrite, but not at all decomposed.

The question as to the source of the iron in these limonite beds, is this: Does it come from the percolation and solution of its pyrite disseminated through the more recent limestone, or does it come from the decomposed pyrite in the slates of the same age? For it will hardly be disputed, that the main source of the supply consisted of pyrite, nor that the decomposition of the slates into clays was the means of providing the impermeable medium in which the iron solutions were caught and imprisoned. If the former hypothesis be the true one, we should expect to see an absence of limestone in the vicinity of the large deposits; for (granting for the moment that the limestone contains enough pyrites to account for the entire deposit (a fact which at least admits of some question), a percolation of water sufficient to oxidize the sulphur of these pyrite crystals and carry away enough iron to produce the beds, would entirely honey-comb and finally, both by solution and attrition, dissipate the limestone bed. But in and near some of the largest limonite beds we find the limestone scarcely weathered, and in few cases, if any, is it rendered ferruginous or even stained to any great degree by chalybeate waters. Indeed, the absence of the familiar iron stain from the calcareous member of this formation is so marked, that this point of difference from the adjacent members of the series cannot fail to arrest attention.

Again the uniformity of the occurrence of these limonite deposits on the skirts of the basin and the lower edge of the elevated limestones and their absence elsewhere, cannot but be the result of the law of their formation. Were these deposits derived from the pyrite disseminated through the limestone there would be no way of explaining the adherence to the rule when the strata were highly inclined or vertical, except by supposing that the ferruginous solution from the limestone found its way across the decomposing slate beds in a direction perpendicular to their planes of lamination—an hypothesis opposed to all experience. But this would not account for the absence of iron oxide on the remaining edges of the limestone itself, for even if we could accept the

flow of the waters through the bedding we should be at a loss to account for the absence of that flow along the planes of bedding. It is objected in short to the hypothesis which would derive the limonite beds from the disseminated pyrite in the overlying limestone. 1st. That the less the limestone actually *overlies*, cæteris paribus, the greater the extent of the limonite deposits. 2d. There is no appearance of wasting in the limestone commensurate with the effect produced, and not even the staining from chalybeate waters which must have accompanied such a genesis. 3d. Very similar deposits are found in regions widely remote from the limestone (thousands of feet of measures below it,—*i. e.*, Hofacker's, and the Cameron Iron Co.'s mine, &c.).

The facts which are most intractable according to the former hypothesis might have been predicted on the latter. A large portion of the slates underlying the Auroral limestones are pyritiferous. A specimen taken from a point on the Peach Bottom Railroad, about five miles southeast of York was selected rather than one nearer to the limestone basin, because in these latter the pyrite is distributed in crystals too minute to be easily counted, while probably not differing materially in the amount of iron contained. A slab of this slate $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ inches was examined to ascertain the number of prints of pyrite crystals which it contained. On the area of the surface $3\frac{1}{2} \times 2\frac{1}{2} = 8.75$ sq. inches there were counted 350 such pits visible to the naked eye.

A micrometric measurement of a large number of these pits gave all intermediate dimensions between $\frac{1}{16}$ and $\frac{1}{48}$ of an inch. Assuming the mean of the cubes of these dimensions or 0.000213 cubic inch as the average size of a crystal, we have 40 such crystals in 1 square inch, occupying 0.00851 cubic inch. In the specimen examined which was $\frac{3}{8}$ inch thick, there were nine layers distinctly visible to the naked eye. Each layer was therefore $\frac{1}{24}$ inch in thickness, and supposing only 0.00852 cubic inch of pyrite in each square inch of laminæ, we have $0.00852 \times 24 \times 12 \times 5 = 12.27$ cubic inches of pyrite in every square inch of area and 5 feet of thickness of these slates. One cubic inch of pyrite weighs 126.1 grains. In the above thickness and area of these slates there are then 1547.25 grains, or in each square foot of the same thickness 222803.57 grains = 31.81 lbs.

This would give us for every mile of outcrop and 1000 feet of arch above the present surface the enormous sum of 168,009,600 lbs. = 75,004 tons of 2240 lbs. But the metallic iron in this mass of slates one mile in length and five feet in thickness would weigh 47729.7 tons, and supposing it to be also oxidized, the anhydrous oxide would weigh 68185.2 tons and as limonite 79691.5 tons.

Assuming $\frac{1}{4}$ of this to be washed into the soil and $\frac{3}{4}$ to be left as earthy iron ochre in the pits originally filled by pyrite in the slates still in place and only partially decomposed,—which lie in juxtaposition to the ore; then every outcrop of these slates one mile long and *one foot* deep has contributed about 20 tons to the deposits. But the entire mass of the rocks

which were formerly above the present surface have been washed away, and with them their 47,730 tons of metallic iron, or their 79,691 tons of limonite (if all this iron was hydroxidized), for every 1000 feet of slope, 5 feet of thickness and 1 mile of outcrop. Added to the smaller contribution of the partially weathered slates at the surface, this gives the total of 79,711 tons of limonite per mile, which has been gradually carried down the dip and segregated among the clays. But these slates are of very great thickness—at least 100 times what has been assumed. Allowing, then, for all loss by transportation into the sea, and through breaks in the continuity of the clay beds to great depths under ground, and for combination with the silicates to form double salts, we still have more than enough to account for all the largest ore banks. It will be asked, why these deposits should bear so close a geographical relation to the limestone basins? An example taken from Feigley & Brillhart's bank in the Dunkard Valley, one mile east of Logansville, is interesting in this connection. Here is the southwest limit of the easterly portion of the small limestone trough which runs parallel with and south of the greater York county synclinal. About a quarter of a mile east of Brillhart's works there occurs a rock almost indistinguishable from the other slates but which contains $\pm$ 33 per cent. (?) of calcium carbonate.

This indicates either that these slates have been subjected to a long soaking with calcium bicarbonate or that the deposits of the carbonate of lime proceeded together with the mechanical deposition of the sediments which formed the slate bed.

In reference to the older limonite formations of Lancaster county, it is said (Vol. I, p. 183): "An interesting inquiry is here suggested as to what can have been the geological atmospheric condition which produced the remarkable percolation which carried down so large an amount of ore out of these ferruginous beds. Was it tepid rain charged with carbonic acid in an early Palæozoic period? Or could it have been a long filtration of surface waters such as now soak the earth? Or are we to surmise an action of internal steam issuing upwards through crevices in the strata in a period of crust movement and disturbance? I am inclined to the first conjecture."

Dr. Hunt in his essay on metalliferous deposits (XII, Chem. and Geol. Essays, Boston, 1875, p. 229), says: "The question has been asked me—Where are the evidences of the organic material which was required to produce the vast beds of iron ore found in the ancient crystalline rocks? I answer that the organic matter was in most cases entirely consumed in producing these great results, and that it was the large proportion of iron diffused in the soils and waters of those early times which not only rendered possible the accumulation of such great beds of ore, but oxidized and destroyed the organic matter, which in later ages appear in coals, lignites, pyroschists and bitumens. Some of the carbon * * is, however, still preserved in the form of graphite," &c.

With reference to the Ferric Sulphide or pyrite, the same author

ascribes its formation to the deoxidizing agency of decaying organic matters out of contact with air on soluble sulphate of lime and magnesia, giving rise, if carbonic acid be present, to Hydrogen Sulphide which "in some conditions not well understood contains two equivalents of sulphur to one of iron." He adds that he has observed that the ferrous sulphide or proto-sulphide of iron in presence of a per-salt of iron loses one-half of its iron, the rest being converted to Ferric Sulphide."

It seems at least a possible explanation for this more prominent determination of limonite along the edge of limestone, that by the oxidation of the pyrites of the slates an equivalent of sulphuric acid in addition to that necessary to form Ferric Sulphate has been produced. That this molecule of free sulphuric acid in its passage over the mica and chlorite slates has dissolved out part of their alkalies, especially soda. That this solution of sodium sulphate has mingled in the clay beds below with the solution of calcium bicarbonate, produced by the drainage of rain waters over the limestone beds, giving rise to sodium bicarbonate and calcium sulphate. That this sodium bicarbonate reacting on the Ferrous Sulphate has precipitated Hydro-Ferrous Carbonate which has been by oxidation rapidly converted to Ferric Hydrate, while the Ferric Sulphate has been immediately thrown down as hydrous oxide. This, be it repeated, is simply one of many explanations which may suggest themselves of the observed fact that the limonite deposits are more frequent and extensive in the neighborhood of limestone deposits.

But though the solutions from such basins may favor the deposition of this ore, they are not always necessary.

It has been incidentally stated that one proof that the supposed iron in limestones was not necessary for the formation of these limonite beds, is that very similar limonite beds are known to occur miles away from any known outcrop of limestone. Such are the beds referred to as the Hofacker, Cameron Co., Keeny Banks, &c., &c., which occur in the lower part of York county and the upper portion of Baltimore and Carroll counties, Maryland. The circumstances of occurrence alike in both cases are the pyritiferous character and the highly inclined strata. The former is much more coarsely porphyritic in the older beds so that the hydroxidation of the pyrites has not been so perfect, and the ore is much more red short than is the case close to the limestone. But the large amount of pyrites in the rocks, in all stages of transition to limonite, would seem to render the search for any other sourse of supply of iron unnecessary.